Towards Interoperability in the UK Construction Design Industry

Mehdi Bavafa[1]

[1]PhD Candidate, School of Built Environment, College of Science and Technology, University of Salford, PH (+44)016156379; Email: m.bavafa@edu.salford.ac.uk

ABSTRACT

The construction design industry involves multiple stakeholders who may carry out their job from widely distributed locations. Therefore, the interaction between those participants is often the cause of mistakes and misunderstandings due to a lack of interoperability. The UK Government will require all those engaged in the design, construction and management of publicly funded buildings and infrastructure to share that process by 2016 (Cabinet Office 2011), However, as stated by UK government reports, the lack of collaboration and interoperability causes not efficient benefit in the business context in the AEC industry.

This research identified unstructured data, information consistency, data and information mapping and knowledge evaluation as the key challenges on the level of interoperability which professionals face constantly in the UK construction industry. This research has been structured using the interpretivist philosophy and qualitative approach to thoroughly explore the challenges of using unstructured data in construction engineering design in the UK. The data collection method of this research will employ semi-structured interviews with structured engineering in the UK and two different cases have been selected to conduct a cross-case analysis that will compare and contrast cases.

INTRODUCTION

The design process in the construction industry involves multiple stakeholders who may carry out their jobs from widely distributed locations (Caballero et al. 2002). Therefore, the interaction between these participants is often the cause of mistakes and misunderstandings due to a lack of interoperability (Serror et al. 2008). In the course of construction engineering, the optimum design is described by a combination of maximum performance, minimum cost and minimum weight, and the design process is an iterative, trial-and-error process (Kiusalaas 1972). Each designer has different experience and skills, and the complexity of the structure causes several re-analyses and re-designs in large projects (Mahfouz 1999). Due to these facts, engineers face different design alternatives. The necessity to minimise the consumption of resources is increasing the adoption of BIM in the construction industry; this will enable the key designers to test the alternative solutions by the adoption of information technologies to achieve an optimal design solution (Kiviniemi and Bichard 2010).

Experienced consultant companies accept that the cost of correction and rework is high. Hence, they are looking for sufficient designers and sufficient systems. The use of BIM causes more visible connections between participants (Alshawi and Faraj 2002). BIM is acknowledged as a solution to reduce errors, as the concept behind BIM is highlighted as a model to improve integration, constructability, information exchange and interoperability (Sacks et al. 2010). This research identified that interoperability is not efficient in the UK. Construction design and explored the challenges that impact on the level of interoperability in the integrated design environment in the UK construction industry. This research will identify the BIM tools for increasing the level of interoperability and the lack of tools that designers are expected to utilise.

INTEROPERABILITY IN INTEGRATED DESIGN ENVIRONMENT

Several reports and pieces of research have highlighted the need for interoperability and collaboration in the AEC industry over the past decade (Egan 2002, Jardim-Goncalves et al. 2006, Grilo and Jardim-Goncalves 2010). The meaning of interoperability has been given by Khemlani (2004) as integrating "the various model-based applications into a smooth and efficient workflow". According to (IEEE 1990), interoperability is defined as "The ability of two or more systems or components to exchange information and to use the information that has been exchanged". By this dialogue it has been identified that interoperability is categorised into two processes: 1- interaction between systems and 2- applicable usage of exchanged data into other systems. There are different forms of interaction between systems or participants: collaboration, coordination and communication. As presented in Figure-8, communication is the underlying part of information interaction and is the exchange of information from sender to receiver components via channel and collaboration. In the coordination layer, activities are aligned to manage scheduling and dependencies.

Figure 1 Interaction between systems

The characteristics of efficient information interoperability handover are stated by (Eastman, 2007) to be ensuring that information is consistently provided, that information is accurately provided and the timing of information should also be specified. "Between 25% and 30% of the construction cost that is due to incomplete, inaccurate and ambiguous production information can be saved" (Richards 2010). In the context of information management in the AEC industry, several standards have been published to provide a method for the development, organisation and management of production information. The buildingSmart published data model standards to develop interoperability through information management in standard protocol. The three sides of the BuildingSmart standards are: 1- Data (IFC) 2- Process (IDM) and 3- Terms (IFD). To address well-documented problems of interoperability within the construction industry, IAI was established. One of the most common data standards promoted by IAI is IFC, which is a non-proprietary object-oriented building data model promoted with a view to enhancing open standards information sharing across various software tools. IFCs provide a capability to capture both tangible (e.g. foundation, door, slab, etc.) and intangible (space, costs, schedule) attributes.

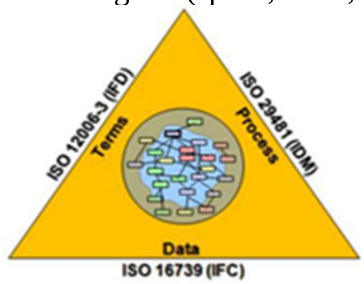

Figure 2 Building Standards from (BuildingSmart, 2013)

According to BS 1192 (The British Standard to Building Information Management), "the fundamental requirement for producing information through a collaborative activity is to share information early, and to trust the information that is being shared as well as the originator of that information" (Richards 2010). For conducting a process map for an information management system inside the semi-intelligent agent, first of all the features of the product (information) should be identified. According to (Leeuwen and Zee 2005), the value of product information for design is categorised into four aspects: 1- Format (Can the information be accessed and applied directly in the design context?); 2- Validity (Is the most actual information available?); 3- Semantic (Is the meaning of the information sufficiently defined and understood?); 4- Timelines (Is the information found and available when needed?). From another point of view, according to (Steel et al. 2012), interoperability is considered on four levels: 1- File level interoperability (the ability of two tools to successfully exchange files); 2- Syntax level interoperability (the ability of two tools to successfully parse those files without errors); 3- Visualisation level interoperability (the ability of two tools to faithfully visualise a model being exchanged) and 4- Semantic level interoperability (the ability of two tools to come to a common understanding of the meaning of a model being exchanged).

EXPLORATORY INTERVIEWS

The design process in the construction industry involves multiple stakeholders who may carry out their tasks in widely distributed locations. Therefore, the interaction between those participants is often affected by insufficient interoperability. In construction design organisations in the UK, a programmed system would carry out part of the information creation, retrieval and delivery on behalf of the users who would also conduct part of the process. In the integrated construction engineering design each Party would have its responsibility to configure their model and interact with others. Hence communication takes place on different levels of interoperability. This research identified the key barriers to interoperable civil engineering design, including: Unstructured Data, Data Mapping, Unstructured Evaluation and Data Consistency. The research also highlighted the key challenges in the process of interoperable construction engineering and also identified that there is a lack of rational platform on the levels of interoperability (Tiers) to link unstructured and semi-structured data to structured data. Lack of data consistency of data was identified as one of the key challenges in the UK construction engineering industry. Distributed data in different databases and different formats and lack of specified timing of data transactions has led to the development of two tiers of servers. The first exchange or share process must happen before evaluation to enable fluent work processes before combining domain-specific models for assessment and coordination. Due to these facts the level of interoperability has been identified by construction design experts in the UK as follows:

1- Simulation Tier
2- File format and standards Tier
3- Structure of the data Tier
4- Semantic Tier

TECHNOLOGY SOLUTIONS IN INTEROPERABILITY TIERS

The construction industry is identified as a slow adopter of IT due to the lack of management support, construction industry fragmentation and user resistance (Bowden et al. 2006). For this reason, the possible value to the construction design industry of conducting IT to increase the level of interoperability has been studied and key Tiers of the interoperability process map have been achieved from a pilot study, including: 1- File format Tier, 2- Standards Tier, 3- Simulation Tier and 4- Semantic Tier.

Simulation Tier. Simulation Tier: since the 1980s there has been a dramatically attention to move from using the computer with algebraic and numerical values to symbolic models and values. In this context, two concerns are argued: 1-converting the understanding of humans of an artefact into a computer representation (coding) and converting a computer representation into human interpretation (decoding) and 2- representing in an explicit way by considering intentions and purposes (Mathur et al. 1993). In this research, the simulation tier is categorised on two levels, which are the visualization level and the semantic level, to study the above-mentioned concerns in a more efficient way. With regard to coding in the visualisation level, designers have several alternatives to input the data in the machine, such as: the colours, textures and size of the model. And with regard to decoding the model, model viewers provide several options to view the model, such as zoom in. With reference to the visual exchange model, the opportunities for leveraging models depend progressively on the semantic level (Steel et al. 2012). In the collaboration design, semantic interoperability concerns will be arising while (Yang and Zhang 2006).1- Sharing of building information modelling occur by different project participants and different definitions of terminologies, different meanings of information and different perspectives about design.2- Disparate design systems and heterogeneous data sources with proprietary information.3- Fundamentally different representation languages and data formats are used in data interchange processes. The most common methods of building design representation are categorised in: 1- Arbitrary codes (highly abstract means of communication and based on common notational language to signify ideas); 2- Graphics (sketches, renderings, perspective drawings and photographs); 3- Scale models (provide information concerning the volumetric properties); 4- Mock-ups (allow the spectator to recognise how the realised design may appear) and 5- Prototype (the mock-ups which are made from actual material to be utilised) (Kalay 2004). The geometric entities, such as points, lines, planes, rectangles, etc. are traditionally represented as 2D CAD and generic 3D modelling programs. In the AEC design industry, general geometric representations are developed to object-based data models. Such data can be rich in information regarding the building lifecycle and can be utilised in visualisation, documentation and analysis (Khemlani 2004). The data contents in building design can be categorised into two kinds of data: 1- geometry and 2- object-based property (Eastman et al. 2009). In the multi-disciplinary building design, any variety of data representation should provide meaningful information for other participants, constructors and clients. In this case, different terms may be utilised for representing the similar perception or a single term for different perceptions (Yang and Zhang 2006). In other words, nevertheless the designers frequently share the same objectives. For instance, when proposing a design solution which meets a client's requirements, they would not essentially use the same terminology to communicate in the design practice.

File Format and Standards Tier. When data are exchanged between BIM tools, relying on just visual aspects is not sufficient. According to the pilot study which this research has already done, there are some other challenges that designers face during the exchanging of data. The designers in different multidisciplinary parties create their models via different tools. Firstly, the modification between different tools has to be translated. Secondly, any change has to be communicated to each design discipline who should adjust their portion of the model due to reviewing the impact on their performance domain (Citherlet et al. 2001). Therefore, the requirement for a building specific data emerged in the context of Computer Aid Design attention. The requirement of direct communication between different applications which are created by different commercial vendors has been responded to by developing specific translators**.**

Generally, the degree of success in exchanging 3D model-based between any two applications will be clarified by three major factors: 1- the performance of the export and import translator functions embedded in the BIM tools; 2- the internal structure of the neutral file format supported by BIM tools and 3- the range of data object types to be communicated (Jeong et al. 2009). The IFC was invented in 1999 by IAI (International Alliance for Interoperability) to support interoperability through various discipline-specific applications which are applied in design, construction and maintenance buildings by capturing information throughout the lifecycle in all aspects of building (Khemlani 2004).

Structure of the data Tier. Whereas there has been lots of progress in the recent construction design technologies, the pilot study illustrated that the interoperability in information flow is not efficient. One of the main issues in this context is unstructured data. According to Caldas et al (2005), structured data are defined as data that have a database and are usually in a software system that uses the form of a database in the background. To clarify, Zhu et al (2007) argued that in the unstructured data there is a serious lack of descriptive data to the documents. For instance, a Microsoft Word document is an unstructured document. However, Microsoft Word allows a user to define descriptive data about the document, such as the name of author and the date. With reference to the pilot study which has been conducted, here a high amount of construction project information is in the form of text-based documents, for instance: contracts, field reports, change orders and requests for information (Caldas et al. 2005). The heterogeneity of information in the AEC/FM industry relates to the coexistence of structured and unstructured data (Kosovac et al. 2000). Structured information indicates it is machine understandable, such as IFC and aecXML. However, unstructured data is human understandable, such as video, audio, image, word processor and HTML document. Kosovac et al. (2000) highlighted that, to fully deliver the interoperability requirements of the AEC/FM industry, it should facilitate the incorporation of structured and unstructured document-based data.

Semantic Tier. Modern construction design projects require accurate sharing of information between multiple disciplines, so that each party manipulates a large amount of documents via various computer-aided management systems. The concept of facilitating information sharing would not be occurred in AEC industry only by human understanding. One of the methods that try to address this problem lies in making the information understandable to both human and machine and information should be labelled in a way which makes its meaning explicit (Pan 2006). The concept of semantic information will be represented in this study in web service and knowledge management contexts.

Ontology is at the heart of the semantic. The shared understanding of a domain which could be communicated between applications and people is afforded by ontology. OWL (Web Ontology Language) is implemented as a language to determine the classes of information and relations between those classes (W3C 2004). Ontology develops an agenda for representing, sharing and managing knowledge within a system. Bodenreinder et al. (2003) argued that there are two types of ontologies: 1-Domain Ontologies, which is a representation vocabulary and classically is represented to particular subject matter. For example, in construction engineering design an ontology for the domain of structural engineering can have elements such as “simulation”, “FEM (Finite Element Method)”, “Steel Cladding System” and relations between elements, such as “a designer simulate steel cladding system using FEM”. 2- Upper level ontology that portrays generic knowledge which holds across many fields.

CONCLUSION

In recent years, interoperability has played a significant role in construction productivity and design performance. Towards improving the interoperability levels in the construction integrated design industry in the UK, this research identified the four main challenges that exist in the industry, which include: Unstructured data, Information consistency, Data and information mapping and knowledge evaluation. These challenges have been determined by a pilot study which was conducted by interviews of experts in the UK construction industry. This study believes that for addressing the challenges the level of interoperability is necessary to be identified for studying the recent technological advantages in each particular tier. The possible solutions to support the interoperability, such as IFC (Industry Foundation Classes), have not addressed the issue of unstructured data due to designers still preferring to capture the information through numbers of text documents and face-to-face meetings and a huge amount of information may be lost and misunderstood in this process. This research categorized the interoperability into four levels, which are: 1- Simulation Tier 2- File format and standards Tier, 3- Structure of data Tier and 4- Semantic Tier. The state of the art has been argued in each tier and in future research the relationship between each level of interoperability and interoperability challenges will be analyzed.

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